FIRE HISTORY OF THE UPPER LAMAR RIVER
DRAINAGE, YELLOWSTONE NATIONAL PARK,
WYOMING

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INTRODUCTION

In the northern Rocky Mountains, fire history studies (Arno 1980, Romme 1982, Romme and Despain 1989, Barrett et al. 1991) have found considerable variation among fire regime patterns for lodgepole pine (Pinus contorta var. latifolia) dominated forests. On relatively productive habitat types at lower elevations, short- to moderately long interval (25-150 yr) fires often occurred in a mixed severity pattern ranging from non-lethal underburns to total stand replacement (Arno 1980, Barrett et al. 1991). But markedly different patterns have occurred in high elevation lodgepole pine forests on relatively unproductive sites, such as in Yellowstone National Park (YNP), Wyoming (USA). On YNP's central plateau, Romme (1982) and Romme and Despain (1989) found that very long-interval (300-400 yr) stand replacing fires occurred in areas underlain by rhyolitic soils, and non-lethal surface fires were rare. In mountainous areas of the park, such as in the Absaroka Range bordering northeastern YNP, scant fire history information existed for more productive lodgepole pine forests occurring on andesitic soils. Therefore, in 1989 a study was initiated in cooperation with YNP and USDA Forest Service Intermountain Research Station to determine historic fire patterns in the upper Lamar River drainage (Fig. 1). The work was especially timely because most of the drainage was severely burned in 1988 (Fig. 2) and historical tree ring data soon will be lost to snag decay. Primary objectives were to: 1) Determine pre-1900 fire periodicities, severities, and burning patterns within the area's major forest types; 2) document and map the pre-1988 forest age class mosaic; and 3) digitize the age class map for inclusion into the park's GIS data base. Secondary objectives were to determine where andesitic site types occur along the fire regimes continuum, and to interpret fire suppression's effects on area forests.

STUDY AREA

The study area encompasses the upper Lamar River drainage, southeast of Soda Butte Creek in the Absaroka Mountains, ranging in elevation from 2000 to 3300 m. (Fig. 2). This 81,000 ha area consists primarily of steep terrain dissected by dendritic stream canyons, several of which originate in alpine glacial troughs along the Absaroka Divide. The west side of the study area is defined by an abrupt change in landform where the eastern edge of the high elevation (2700+ m) Mirror Plateau forms a primary divide between the Lamar and upper Yellowstone Rivers. Prior to the 1988 Clover-Mist Fire lodgepole pine-dominated forests, with understories dominated by shade tolerant subalpine fir (<u>Abies lasiocarpa</u>) and Engelmann spruce (<u>Picea engelmannii</u>), occupied ~36,200 ha (45%) of the study area in canyon bottoms and slopes below ~2650 m (Despain 1990). These forests are more moist and productive than those on YNP's rhyolitic central plateau due to the more nutrient-rich andesitic soils and increased precipitation from the Pacific maritime storm track near high mountain divides (Steele et al. 1983). Throughout YNP, extensive even-age classes of lodgepole pine regenerated shortly after stand replacing fires that exposed mineral soil seedbeds and released seeds from serotinous cones (Taylor 1974, Romme and Despain 1989, Despain 1990). The rest of the area (55%) is occupied by uneven age forests, grasslands, or rocklands. For example, the northwest corner of the study area contains the uppermost extension of high elevation (~2000 m) <u>Artemisia</u>/bunchgrass types in the adjacent Lamar Valley, reflecting the dry continental precipitation regime typical of YNP's lower elevations (Steele et al. 1983). Uneven age forests are interior Douglas-fir (<u>Pseudotsuga menziesii</u> var. <u>glauca</u>) stands on dry sites adjacent to the grasslands to 2400 m, and high elevation stands dominated by whitebark pine (<u>Pinus albicaulis</u>) near alpine timberline (~3100 m).

Following are common forest habitat types defining potential vegetation in

the study area (Steele et al. 1983, Despain 1990): 1) _P. menziesii_/_Symphorocarpus albus_ and _P. menziesii_/_Calamagrostis rubescens_ near the grassland-forest ecotone, 2)_A. lasiocarpa_/_Linnea borealis_ and _A. lasiocarpa_/_Vaccinium globulare_ (_V. globulare_ and _V. scoparium_ phases) in moist draws and sheltered north slopes at low- to mid elevations, 3) _A. lasiocarpa_/_Vaccinium scoparium_ (_V. scoparium_ phase) on most well drained aspects at mid- to upper elevations, and 4) _A. lasciocarpa_/_V. scoparium_/(_P. albicaulis_ phase) on most slopes above 2650 m. and on exposed high elevation ridges.

METHODS

Fire history was determined by identifying fire-initiated seral age classes (even age lodgepole pines) and occasionally by dating basal fire scars on Douglas-firs. Because fire scars were uncommon in the lodgepole pine forest (Romme 1980b, Romme and Despain 1989) the fire-year origins of 98 sample stands (Fig. 2) were estimated from 431 increment cores of fire-initiated age classes (primarily 1988 fire-killed trees). Then a map of the pre-1988 forest age class mosaic was compiled (Heinselman 1973, Tande 1979, Romme 1982, Barrett and Arno 1988, Romme and Despain 1989). At the Lamar Valley grassland ecotone, old Douglas-firs with multiple fire scars were common (Houston 1973) and 8 partial cross sections were sawn from trees to estimate longterm fire history in 3 stands (Arno and Sneck 1977).

A 1:62,500 forest cover type map derived from analysis of aerial photographs (Despain 1986) was used to identify the locations of different-age lodgepole pine stands for sampling. Stand-initiation years were identified by increment boring dominant lodgepole pines within 30 cm of ground surface (Barrett and Arno 1988). Since large numbers of lodgepole pines usually become established within several years after stand replacing fire (Taylor 1974, Romme 1982,

Despain and Romme 1989), fire year estimates were derived by using the earliest establishment year sampled within a given age class.

To document postfire succession before 1988, tree composition and age structure was inventoried by establishing from one to three representative circular macroplots (375 m^2), depending upon stand extent and variability (Arno and Sneck 1977, Pfister and Arno 1980). Live stands were used whenever possible to determine representative tree composition and habitat types, but it usually was necessary to reconstruct stand composition in 1988-burned stands using tree crown habit and bark traits as diagnostic aids. Percent canopy coverage and representative ages were sampled for each tree species in 4 size classes: saplings (0-10 cm in diameter 1.3 m above ground), poles (10-30 cm), mature/overmature trees (30-76 cm), and large diameter (overmature) trees (>76 cm).

Fire scar years were estimated by sanding and dating sawn fire scar cross sections under magnification (Arno and Sneck 1977). The age-class increment cores were sanded and the annual growth rings were counted from the appropriate cambium year (e.g. 1988) to pith. Final estimates for stand initiation years (approx. fire yrs) comprising the lodgepole pine age class mosaic were made using the following criteria: similar tree establishment years (typically within a 5 yr range) were necessary from at least three seral trees per stand and, in the absence of datable fire scars or fire atlas records, the earliest tree establishment year was used to approximate the actual fire year.

The forest age class map was produced by labelling the stand initiation years at the appropriate sample locations. Then 1:20,000 aerial photographs were used to edit, when necessary, the stand boundaries shown on Despain's (1986) map of broadly defined age classes. Tree crown texture, tone, relative height, and relative diameter were used to extrapolate stand ages to any unvisited stands with similar canopies. When stand age extrapolation was not

feasible, relative age labels (e.g. "1800s regeneration") were assigned to the unvisited stands by comparing their canopy traits to those of sampled stands. The map was digitized and entered into a geographic information system using GRASS software (Geographic Resource Analysis Support System, U.S. Army Corps of Engineers, 1990) for use in generating area statistics for various age class categories.

Two methods were used to calculate fire frequency. A master fire chronology (Arno and Sneck 1977, Romme 1980a) was compiled for each sample stand, showing the fire years estimated from the age class and fire scar sampling. Then a master fire chronology was developed for the lodgepole pine forested portion of the study area by listing the age classes that regenerated after stand replacing fires. Mean fire intervals (MFIs) were calculated by dividing the time period between the first and last fires by the number of intervals. When stands produced evidence of only one fire interval, fire frequency was estimated by determining a multiple site average fire interval (MAFI) (Barrett and Arno 1988). MAFI represents a mean of single fire intervals determined from a network of stands occupying similar habitat types. Postfire tree succession was examined by graphing pre-1988 canopy coverages of each tree species by the four sampled size classes and labelling the ages sampled from each class. Final interpretation of successional patterns was based on an examination of each stand's structure and age patterns relative to its fire history.

RESULTS AND DISCUSSION

Pre-1988 Burning Patterns. The master fire chronology extends back 250 years to 1737, representing a continuous record of stand replacing fires that initiated the pre-1988 burn mosaic (Fig. 3). Additionally, high elevation stands dominated by whitebark pine, and lower elevation stands dominated by

Douglas-fir, often dated back to the 1500s but past fires are largely unmappable in uneven age forests (Arno and Sneck 1977, Barrett and Arno 1988). The increment core data for lodgepole pine stands suggested 23 stand replacing fires between 1737 and 1987 (study area MFI: 11 yr) and one age class predated 1737 (~1647)(Figs. 3, 4). The scarcity of >250 year old stands is largely attributable to 7 large fires during the 115 years between ~1740 and ~1855, which produced ~70% of the lodgepole pine mosaic (Figs. 3, 4). Four fires were noteworthy for their large size and together produced ~51% of the mosaic: ~1756 (4080 ha; 11% of the mosaic), ~1773 (7141 ha; 20%), ~1820 (3099 ha; 9%), and ~1835 (3967 ha; 11%). Because old fire scars generally were absent in lodgepole pine stands, disjunct polygons of closely similar age occasionally might have been erroneously attributed to separate fire events, especially for the 1700s period. Clearly, however, major stand replacement burning occurred between ~1740 and ~1855. Comparison with Houston's (1973) fire chronology from Douglas-fir stands bordering northern YNP grasslands (1-48 km west of the study area, including the lower to middle Lamar River drainage) suggests close agreement with 4 major fire years that I interpreted for the upper Lamar River drainage. Houston's (1973) estimates, more precise because they were based solely on fire scars, suggested widespread fires in northern YNP in 1738, 1758, 1776, and 1856, compared with my estimates of ~1740, ~1756, ~1773, and ~1855 based on seral pine regeneration. Subsequent to the mid-1800s the master fire chronology suggests that a relatively fire free interval of 130 years occurred between ~1855 and 1987 (Fig. 4), wherein only 8% of the mosaic was burned by 14 fires (just 2% burned between 1900 and 1987). Similarly, Houston's (1973) data suggested only one important fire year (1870) occurred in northern YNP between 1850 and 1972. Southwest of the study area, in lodgepole pine forests on ~130,000 ha of YNP's central plateau, Romme (1982) and Romme and Despain (1989) also found several extensive fires occurred between ~1730 and ~1795, but this

was followed by a ~200-year relatively fire-free interval until 1988.

In interpreting fire history I recognized that estimates of past fire sizes would be just a vignette of actual hectares burned in the upper Lamar area. First, successive stand replacing fires obliterated fire history evidence over time thus masking the margins of the oldest burns. Second, unlike today's readily observable 1988 burn area, the fire patterns discussed above apply only to even age lodgepole pine stands that comprise just 45% of the study area. Spread patterns cannot be mapped for the 55% of the area occupied by vegetation that also must have burned during past fires--in whitebark pine, Douglas-fir, and grassland ecosystems. (By comparison, the lodgepole pine forest dominates most of YNP's central plateau [Romme 1982, Romme and Despain 1989]). Thus, for example, relict age classes attributed to the ~1773 fire (20% of the 1988 pre-burn mosaic) certainly yielded a substantial under-estimate of the actual burned hectares and this fire might well have been similar in scale to the 1988 fire. Romme and Despain (1989) stated that by 1988 the park contained many old stands that would have been moderately to highly flammable during severe fire weather. Data for lodgepole pine in the upper Lamar drainage support their interpretation about age class proportionality since ~70% of the mosaic was between 130-341 years old in 1988. Moreover, substantial areas of the upper Lamar drainage were occupied by high elevation whitebark pine stands between 300-500 years old (Despain 1986, Despain 1990).

<u>Fire Regimes</u>.

<u>Lodgepole Pine Cover Type</u>. Fire patterns also were examined at the stand level of analysis for major forest cover types. Most lodgepole pine stands were even aged and lacked fire scarred trees (as per Romme 1982, Romme and Despain 1989)(Fig. 5), suggesting a predominant pattern of stand replacing fires (only 3 of 98 sample stands in this cover type were 2-aged, having

overstory trees with a single basal fire scar). An initial estimate of average interval for stand replacing fires in lodgepole pine was derived by listing all fire intervals ending with the 1988 Clover-Mist Fire, then calculating MAFI (Table 1). Based on 23 stands that were replaced in 1988, intervals ranged from 47 to 341 years and MAFI was 168 years. This probably represents an underestimate, however, because 5 intervals (22%) were between 47 and 90 years long and researchers (Arno 1980, Romme and Despain 1989, Despain 1990, Barrett et al. 1991) suggest that such short intervals are unusual for lodgepole pine stand replacement. These young age classes represented <4% of the pre-1988 lodgepole pine mosaic, and an even smaller percentage experienced replacement burning during 1988. Therefore, when frequency calculations were based on 17 age classes that comprised most of the 1988 burned area, intervals ranged from 113 to 341 years and MAFI was 210 years (these age classes comprised 82% of the pre-1988 mosaic). If several decades of efficient fire suppression before 1972 delayed replacement of some old age classes (Romme and Despain 1989) then 210 years represents a somewhat longer than natural mean fire interval. The best estimate probably lies somewhere between the above results but closer to the latter, thus, ~200 years.

Occasionally there was evidence of partial stand replacing fires occurring in lodgepole pine stands, as opposed to representing merely a "burn margin" effect (Romme 1980b, Romme 1982, Romme and Despain 1989) where a few trees might be scarred at the edge of a stand replacing fire. On the cental plateau, for example, Romme (1982) and Romme and Despain (1989) found few scarred trees and little associated tree regeneration. But 5 dry-site stands in the upper Lamar drainage had single basal fire scars and a 2-age seral component (Fig. 6), a result of surface fire spreading into stands after making stand replacing runs nearby. Despain (1990) indicates that gently sloped, well drained sites occasionally experience low intensity surface fires of limited extent; the age

class map generally supports this interpretation since 2-age stands totalled <2% of the lodgepole pine mosaic and mean stand size was 118 ha. The stand plots and increment cores suggested that the surface fires killed as many as 50% of the overstory trees and triggered a new seral age class ~20-80 years after the former age class became established (MAFI for surface fires: 57 yr).

Descriptions of fire behavior potential for various lodgepole pine successional stages in YNP (Romme 1982, Despain 1986) suggest that stands between 100-300 years old are transitional between relatively non-flammable young stands and highly flammable older stands. Most stands (68%) in the upper Lamar drainage were between 130 and 250 years old in 1988 (mean age: 198 yr) and Despain (1986) suggests that they would burn only during extreme conditions, as in 1988. It therefore is possible that even some of the longest fire intervals in Table 1 are atypical of primeval fire intervals, but several factors suggest that a ~150-250 year interval range is in fact characteristic for lodgepole pine in the upper Lamar drainage: 1) I found just one comparatively old (~1647) age class amounting to <3% of the lodgepole pine mosaic; under a regime of very long interval stand replacing fires, however, the mosaic certainly would have contained a greater mix of old stands (Romme 1982), 2) the 1988 fire may not have been unprecendented because the data produced evidence of other extensive fires (e.g. ~1773 fire), and 3) the upper Lamar fire intervals are similar to those found in other studies of lodgepole pine on mountainous terrain (Arno 1980, Barrett et al. 1991). Finally, some fire intervals in Table 1 might be considerably longer than normal because of fire suppression (Romme and Despain 1989)--the study area contains substantial areas of dry grasslands extending south from the Lamar Valley, where ignitions were routinely suppressed for nearly a century (Houston 1973, Taylor 1974, unpub. reports on file: YNP Fire Cache).

These fire regime patterns differ from those on YNP's central plateau (Romme

1982, Romme and Despain 1989). Romme (1982) hypothesized that the combined effects of unproductive sites (sparse live fuels on rhyolitic soils), very slow fuel accretion (dead fuels), and the plateau's gentle terrain often discourage fire spread, producing very long intervals (300-400 yr) between stand replacing fires. Forests in the upper Lamar drainage occupy more-productive sites (increased understory fuels) on steeper terrain, where south slope fuels are more prone to drying and where fuel pre-heating occurs more readily during fires. In such ecosystems, where yield capability can be much as 3 times greater than on plateau sites (Steel et al. 1983), fuel succession can follow more complex pathways than that modelled by Romme (1982), depending on site fire history and other mortality factors. Brown (1975), for example, states that during early stages of stand succession lethal fire can recur in dense fuels provided by fallen snags and the developing understory. If such a "reburn" occurs, post-fire stand flammability can remain relatively low for several centuries because the dead fuels created by the previous fire are largely consumed, and subsequent restocking often is low. In the absence of a reburn, the initial moderate- to high stand flammability usually is followed by a period of relatively low flammability for several decades or more after snag fall, then fuels increase gradually between the mature and overmature stages. In this case stand replacing fire might then be delayed for 150 years or more, with actual replacement intervals varying according to site type, stocking levels, mortality induced by disease and insects, and other factors (Brown 1975). In the upper Lamar area, several fires before ~1855 might have reburned some sites after comparatively short intervals; 4 large fires appeared to have roughly bisected adjacent age classes that ranged in age from 47 to 82 years, suggesting the fires actually killed portions of the stands (e.g., see ~1773 and ~1855 classes, Fig. 3). These data were not used in estimating MAFI for lodgepole pine, however, because pre-1988 mosaic patterns are not a reliable

indicator of fire intervals.

Elevational differences between the 2 study areas also might contribute to the difference in fire regimes: mean elevation on the plateau study areas is ~2500 m (Romme 1982) whereas lodgepole pine stands in the upper Lamar area range from ~2070-2650 m. Fire frequencies estimated for stands in the upper part of this elevational range near the whitebark pine forest ecotone (Abla/Vasc/Pial h.t.)(discussed below) are similar to those for the plateau forest (Abla/Vasc/Vasc and Abla/Vasc/Pial h.t.). In sum, the fire regime patterns found for lodgepole pine in the upper Lamar area more closely resemble those of mountainous lodgepole pine forests elsewhere in the Northern Rockies (Arno 1980), such as in Glacier National Park (USA) (Barrett et al. 1991).

Whitebark Pine Cover Type. Despain's (1986, 1990) maps displaying YNP forest cover types suggest that the whitebark pine type occupies as much as 40% of the study area above ~2650 m. It was not possible to develop a detailed age class map for this highly mixed-age forest (Romme 1980) but sampling indicated that this cover type had the most fire regime variability in the study area. Fire patterns became more complex as the sampling progressed upward from the broad lodgepole pine-whitebark pine forest ecotone to wind-swept timberline stands dominated by stunted whitebark pine and subalpine fir, and krummholz. Increment cores from 11 whitebark pine stands (Table 2) suggested that whitebark pines commonly reached 300-450 years old before succumbing to lethal fires or other factors. Severity patterns in lower elevation whitebark pine stands were similar to those in the adjacent lodgepole pine forest, but MAFI for stand replacing fires based on 8 stands that burned in 1988 was nearly a century and a half longer (~340 yr vs. 200 yr)(Tables 1, 2). Despain (1990) states that very slow fuel accretion typically produces 300-400 year stand replacement intervals and that large fires spread through this zone only during extreme fire weather, as in 1988. Old whitebark pines in upper subalpine

stands commonly had 1 or 2 scars from surface fires of varying severity, and even during the 1988 fire many timberline stands experienced only non-lethal severity or partial stand replacement. MFIs including both underburns and replacement fires for 4 stands in or near the timberline zone ranged from 66-204 years (grand mean: 131 yr)(Table 2). Two small krummholz islands separated by as little as 50 m showed poor fire year correlation between stands when fire scars on 6 trees were bored (Barrett and Arno 1988), supporting Despain's (1990) interpretation that high elevation surface fires usually were very limited in extent. Fischer and Clayton (1983) state that stand fire history in the upper subalpine is difficult to interpret because fires often burn only one or two trees. Moreover, Arno and Hoff (1989) indicate that stand structures are highly complex (Fig. 7) because of variations in site type and fire occurrence, epidsodic germination from animal seed caches, and other factors.

Douglas-fir Cover Type. The Douglas-fir cover type occupies an estimated 10-15% of the study area along the grassland/forest ecotone (Despain 1986, 1990). These relatively open stands are highly uneven-aged (Fig. 8) with dominant Douglas-firs frequently 300-500 years old (Houston 1973). Houston (1973) sampled fire scarred trees throughout much of YNP's northern range and found that frequent surface fires (20-50 yr intervals) before ~1880 consumed small understory trees without killing most mature Douglas-firs, followed by a virtual absence of fires after 1880. Sampling in the study area verified this pattern. Old Douglas-firs commonly had 2-6 basal fire scars, and samples from 3 stands along the forest edge near lower Soda Butte Creek suggested 15 fires between ~1534 and 1991. Most pre-1880 fire intervals were between 15 and 50 years, and the 3-stand cluster produced an MFI of 28 years for that period. Only 2 fires occurred after ~1870 (1940, 1988) and one Douglas-fir stand had not burned for ~121 years. This is an unusually long fire interval for such dry sites (Houston 1973, Arno 1980, Arno and Gruell 1983) and evidently is a

result of efficient fire suppression for nearly 100 years in YNP's northern range (Houston 1973), possibly exacerbated by ungulate overgrazing (Kay 1990). Houston's (1982) comparison of old photographs with modern retakes found that grasslands and adjacent dry Douglas-fir stands have markedly increased in densities of fire sensitive species. Many Douglas-fir stands, especially those on moderately moist sites, developed relatively dense understories representing ladder fuels into the overstory canopy (Houston 1973, Houston 1982, Arno and Gruell 1986), fuels that can enhance the spread of stand replacing fires. In fact, the Clover-Mist Fire killed a number of old Douglas-firs in and near the study area and this clearly was an unusual event during the last several hundred years.

<u>Effects of Fire Suppression</u>. Three cultural periods have been defined for the time span covered by YNP fire history data (Houston 1973, Taylor 1974, Romme and Despain 1989): 1) the Prehistoric Period (pre-1886), 2) Complete Suppression Policy (1886-1972), and 3) the Natural Fire Program (1972 to present). Fire suppression apparently was effective in remote areas of the park for only about 30 years before the natural fire program (Taylor 1974, Romme and Despain 1989), suggesting a logical fourth category for YNP's central plateau. However, that period would be less applicable to the northern portion of the upper Lamar study area because it adjoins a heavily travelled grassland valley where many fires were extinguished beginning in the late 1800s (Houston 1973, Taylor 1974).

Indians occupied the greater YNP area for 7000-10,000 years B.P. (Wedel et al. 1968, Lahren 1971) and tribes throughout western North America commonly ignited fires both inadvertantly and by design (Barrett and Arno 1982, Pyne 1982, Gruell 1985). Diaries, park superintendents' reports, and other early-day records indicate that Indians, explorers, miners and other travellers

contributed to ignition frequency in YNP until the late 1800s (Taylor 1974), particularly in the hunting and travel areas provided by northern YNP's grassland valleys (Houston 1973). Houston (1973) found evidence of a large fire in 1870 in the Lamar River Valley and adjacent areas, and journals (Gillete 1870, Bonney and Bonney 1970) stated that Indians ignited the fire to drive game. (Data for the upper Lamar study area indicate that a ~1870 fire replaced ~770 ha of lodgepole pine age classes near lower Soda Butte- and Cache Creeks, adjacent to the Lamar Valley grassland). Houston (1973) felt it would be difficult to quantify humans' role in igniting fires during the pre-fire suppression era, particularly in remote areas of the park because there is only limited evidence of early human activities. However, Romme and Despain (1989) state that ignition sources have been much less important than weather and fuel conditions in producing major fires in subalpine areas.

Annual fire reports for the period 1930-1991 (unpub. reports on file: YNP Fire Cache) also produced evidence of efficient fire suppression, particularly near the Lamar Valley (pre-1930 fire records are highly sporadic [Taylor 1974]). The 6-decade record shows that 47 fires occurred in the study area, 19 of which occurred during the post-1972 Natural Fire Program. The 1988 Clover-Mist Fire was the only major stand-replacing event in this century, and 42 of the 47 fires (89%) were <1 ha in size. Of these 42 tiny fires, 25 were suppressed ignitions between 1930 and 1972, and the 17 remaining fires were small prescribed natural fires after 1972. Eight of 28 suppressed fires between 1930 and 1972 occurred on the dry grasslands near Soda Butte Creek, and 3 were caused by humans.

Some suppressed fires clearly had potential to spread. First, 7 fires occurred in or near mature- to over-mature stands during known drought years (1936, 1940, 1949, 1960)(unpub. reports on file: YNP Fire Atlas, Romme and Despain 1989, Balling et al. [in prep]). Second, 8 ignitions occurred in dry

grassland fuels where unhindered fires can spread rapidly to adjacent forests. And third, efficiency of both detection and suppression apparently decreased with increasing distance from roads (Romme and Despain 1989), and allowed several backcountry fires to spread to substantial size before suppression. While most ignitions in YNP had little potential for growth (Romme and Despain 1989, Balling et al. [in prep]), a few might have become significant stand replacing fires and possibly influenced the eventual 1988 burn pattern (Romme and Despain 1989). Spreading fires also would have continued the natural frequency in grasslands and dry stands dominated by Douglas-fir and aspen (Populus tremuloides).

Estimates of fire cycle (Romme 1980a) were derived for the lodgepole pine cover type (N = time required to burn an area equivalent to the entire 36,210 ha lodgepole pine mosaic). Nine fires occurred between ~1737 and 1800 and produced 57% of the 1988 pre-burn mosaic. At that rate, theoretically 90% of the area would have burned in the 100 years between 1700-1800, thus fire cycle equals 111 years. Ten fires between 1800 and 1900 produced 39% of the mosaic, yielding a fire cycle for that century of 256 years. Four stand replacing fires between 1900 and 1972 (Fire Suppression Period) produced only 2% of the mosaic, and fire cycle would be 3703 years for the 20th century had that fire pattern continued. The sheer magnitude of the 1988 Clover-Mist Fire was revealed, however, when fire cycle was calculated for the 2-decade Natural Fire Program (1972-1991): fire cycle for the 20th century shifted abruptly to 25 years, because that one event burned an estimated 75% of the lodgepole pine mosaic. Balling et al. (in prep) analyzed wildfire-climate relationships for the last 95 years in YNP and found a trend toward increasing summer temperatures and pre-fire season drought, as well as a positive correlation between large fires and years marked by drought and high temperature. Yet, compared to the previous 2 centuries, there was a 15- to thirtyfold increase in

fire cycle rate between 1900 and 1972, followed by a dramatic alteration of the forest mosaic in just one fire season. This appears to be further evidence that fire suppression had interrupted area fire frequency before YNP's change to a natural fire policy.

Romme and Despain (1989) analyzed lodgepole pine succession on YNP's central plateau and concluded that the 1988 fires were a primarily natural phenomenon because large areas of the park were occupied by old stands that had reached moderate- to high potential flammability by the late 1900s. They also stated that several decades of efficient fire suppression might have precluded a few stand replacing fires, thus somewhat reducing mosaic diversity. In studying western larch (Larix occidentalis)-lodgepole pine forests in the North Fork Flathead Valley of Glacier National Park (USA), Barrett et al. (1991) interpreted that artificially induced mosaic homogeneity had promoted more extensive stand replacement burning during a wildfire in 1988. In YNP, however, the unusually severe fire weather in 1988 (Romme and Despain 1989, Balling et al. [in prep]) allowed fires to destroy substantial areas of very young age classes, so Romme and Despain (1989) concluded that the amount of stand replacement burning ultimately would have been similar regardless of past suppression activities. Given the inherent uncertainty in interpreting fire history, their assessment also seems plausible for the upper Lamar River drainage. Currently, because a new forest mosaic blankets so much of the park, fire managers might instead wish to focus on ecosystems with historically short fire intervals, such as the grassland, Douglas-fir, and aspen communities in northern YNP.

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<u>List of Figures</u>

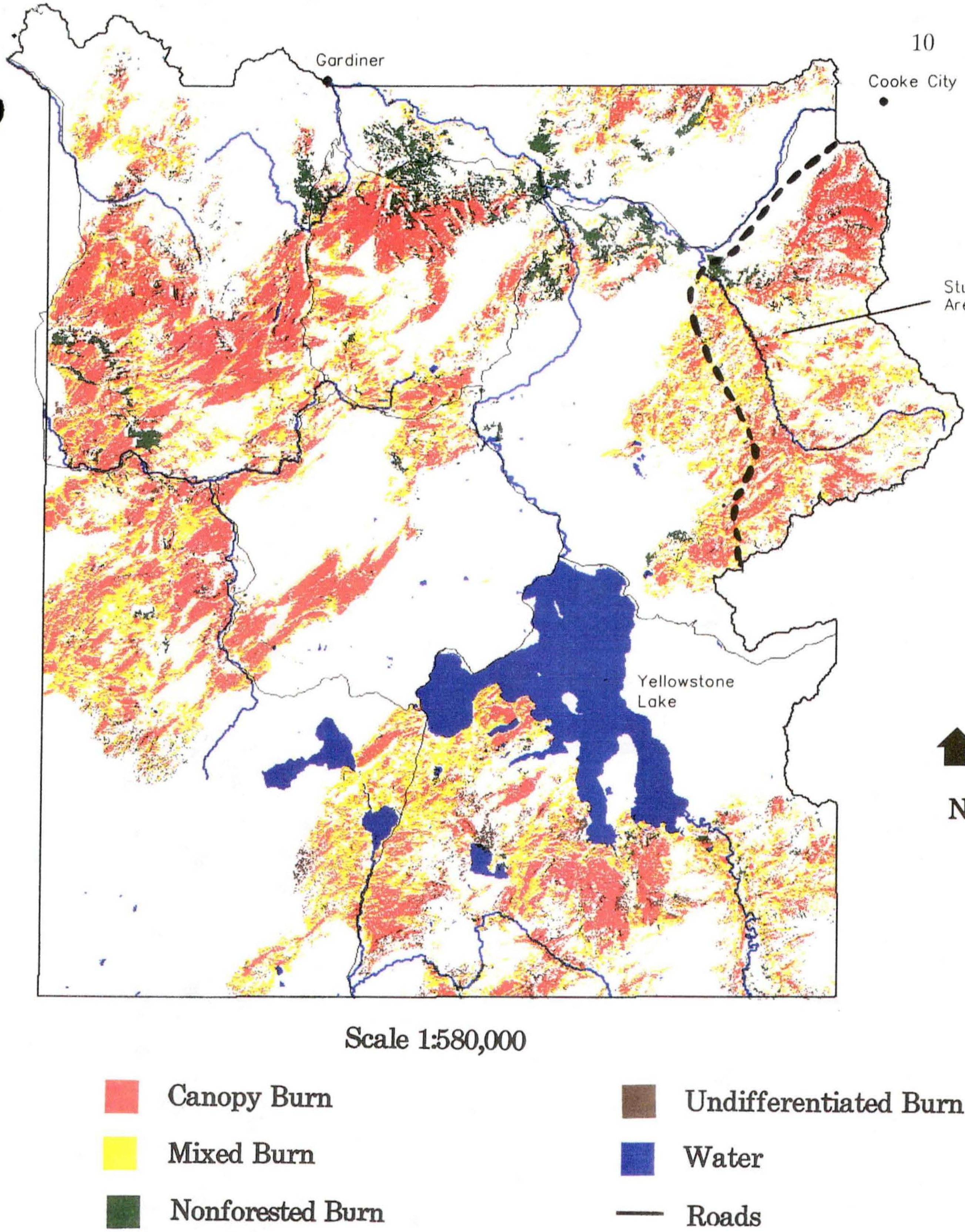

Gardiner
Cooke City
Study Area
Yellowstone Lake
N
Scale 1:580,000
Canopy Burn
Mixed Burn
Nonforested Burn
Undifferentiated Burn
Water
Roads

Figure 1

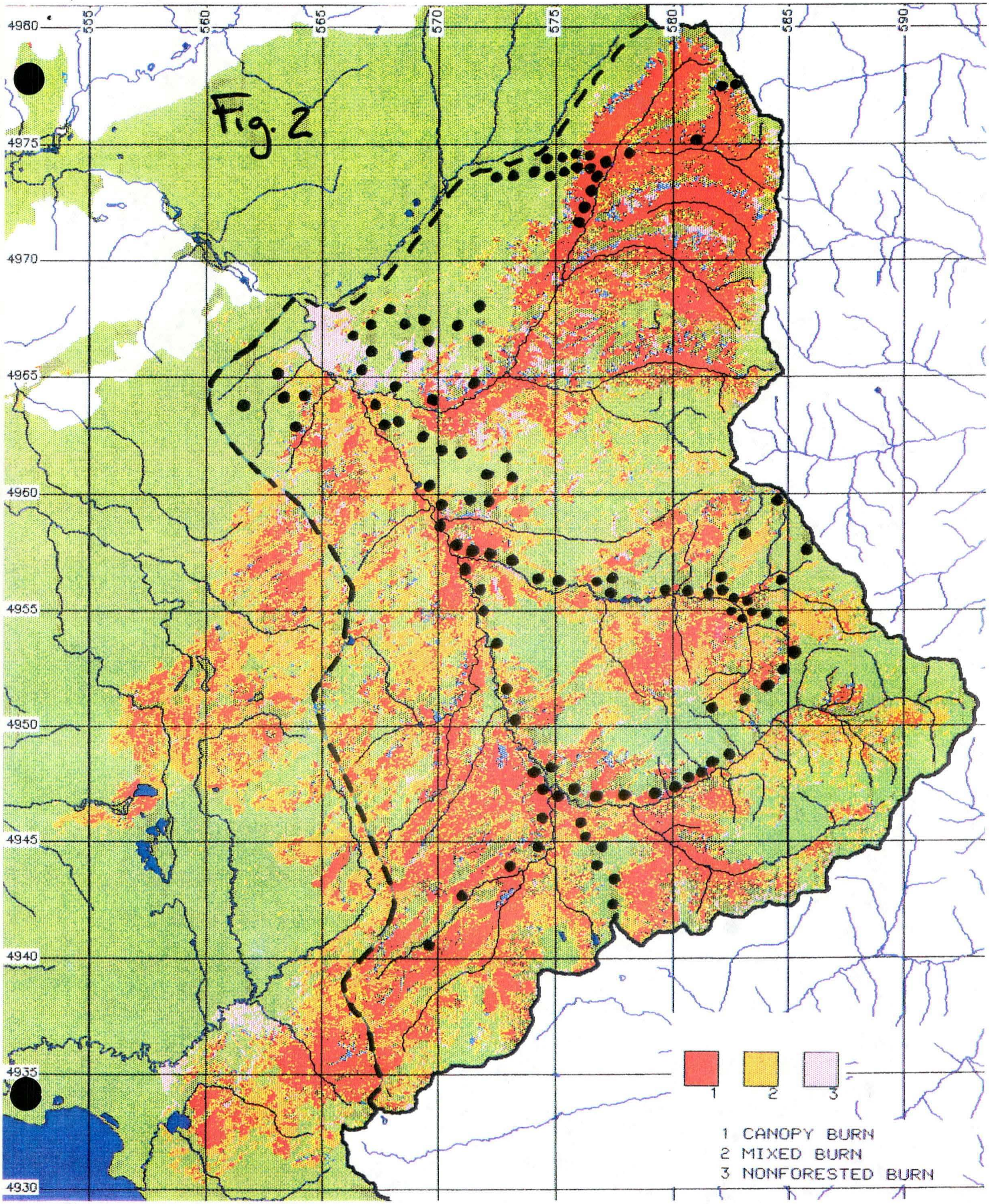
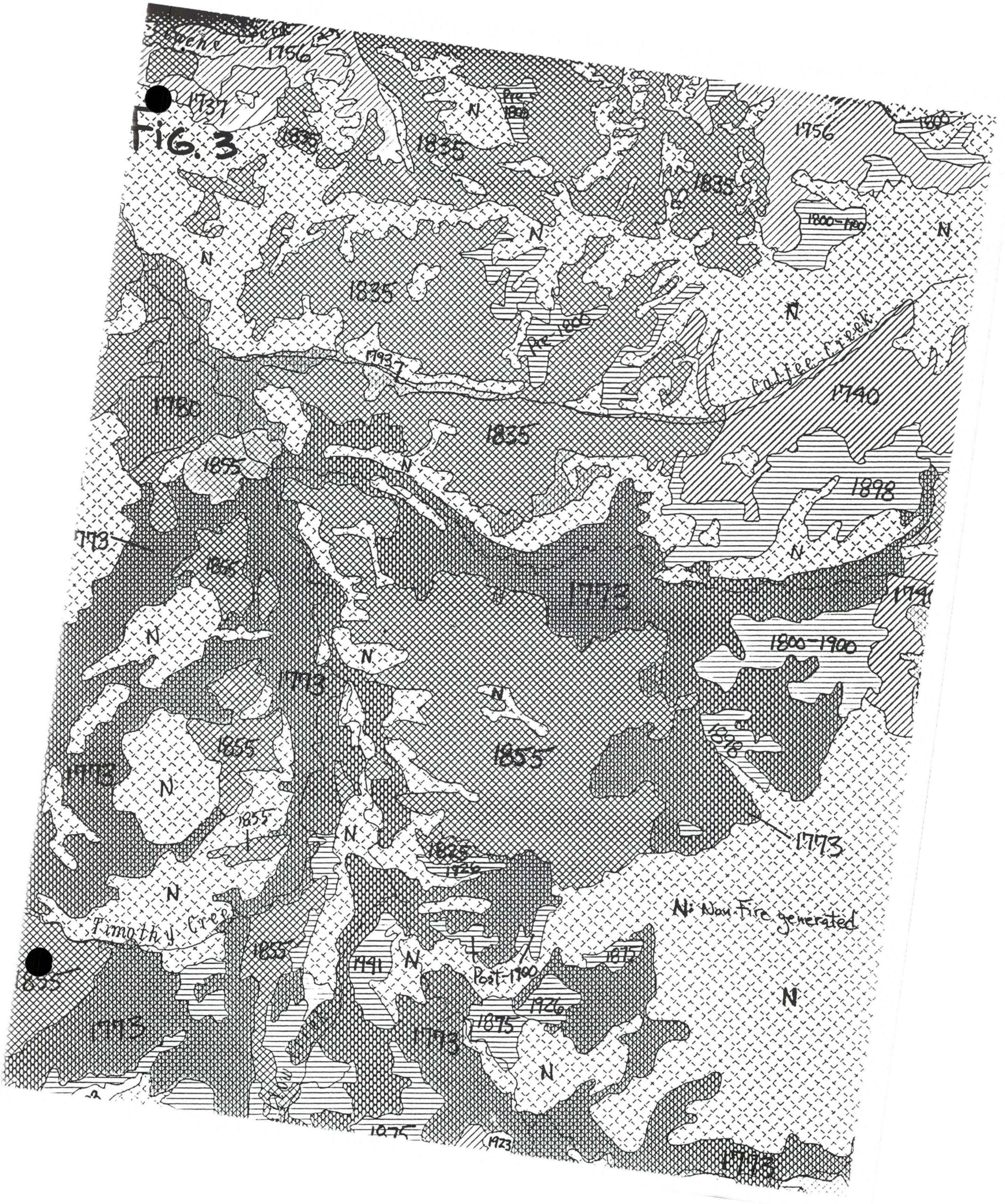


Fig. 2
4980
4975
4970
4965
4960
4955
4950
4945
4940
4935
4930
555
560
565
570
575
580
585
590
1
2
3
1 CANOPY BURN
2 MIXED BURN
3 NONFORESTED BURN

FIG. 3



1756
1737
1835
Pre 1800
1835
1756
1835
1800-1900
N
1835
Pre 1800
1793
Coffee Creek
1740
1780
1835
1895
1898
1773
1855
1773
1800-1900
1773
1855
1898
1773
1855
1825
1926
1773
N: Non-Fire generated
Timothy Creek
1855
1941
Post-1900
1875
1926
1875
1773
1773
1923
1773

Fig. ~~3~~ 4. Major fires between 1647 and 1991 by percent of total lodgepole pine forest burned (dashed lines indicate fires that burned less than 2% of area). Parentheses display percent of area burned per century after 1700, as well as fire cycle rate in years.

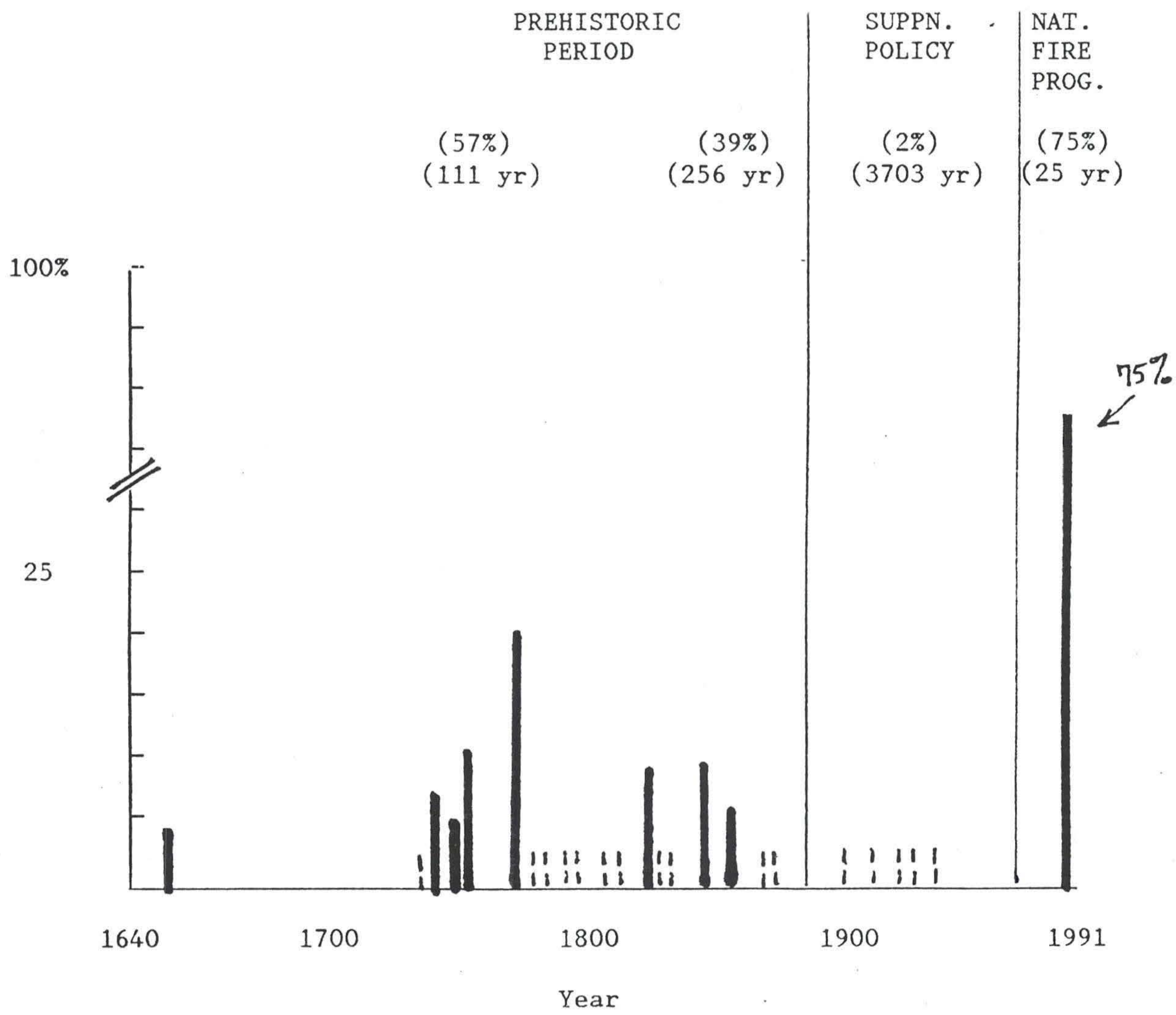


Fig 5

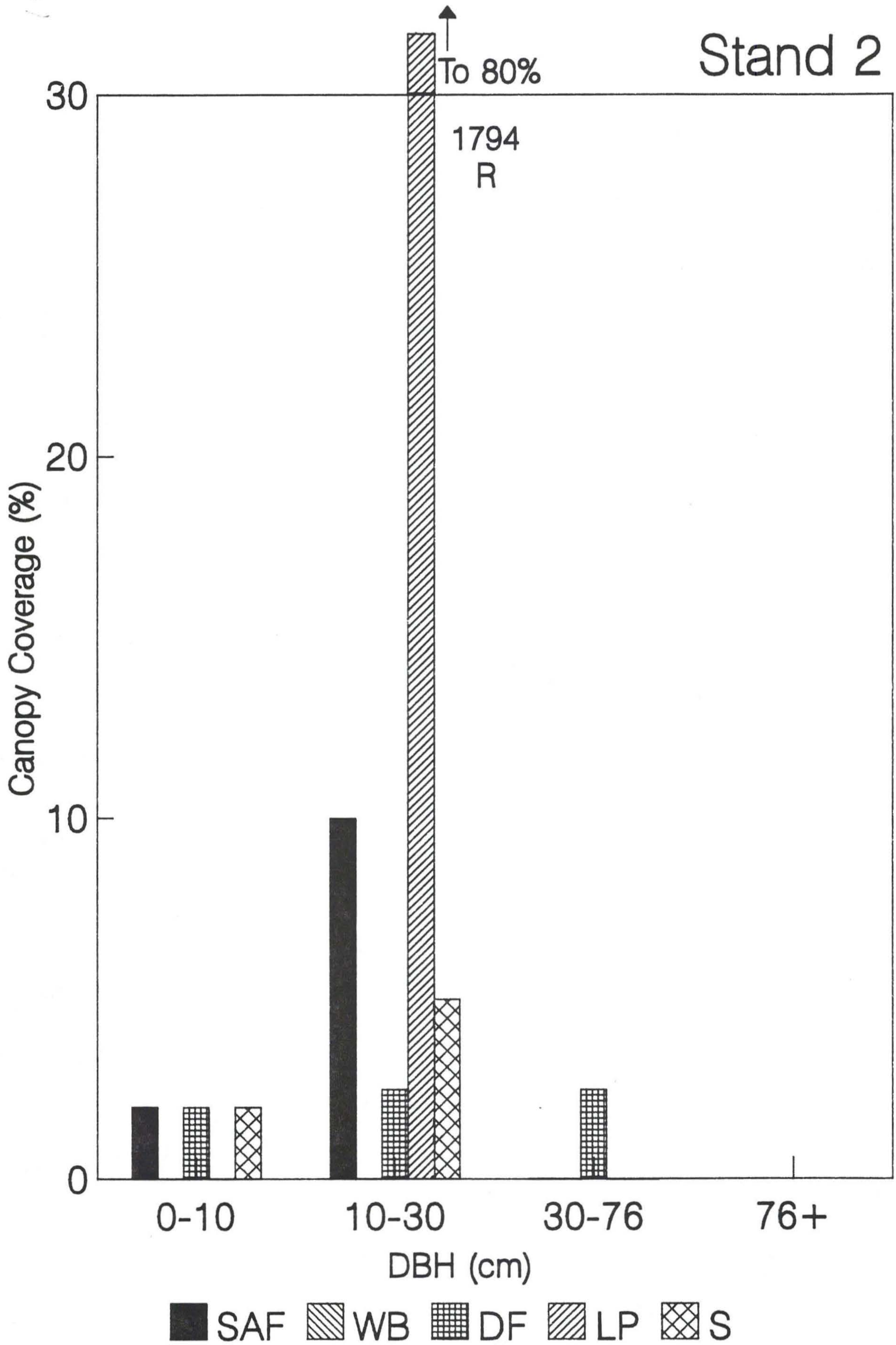
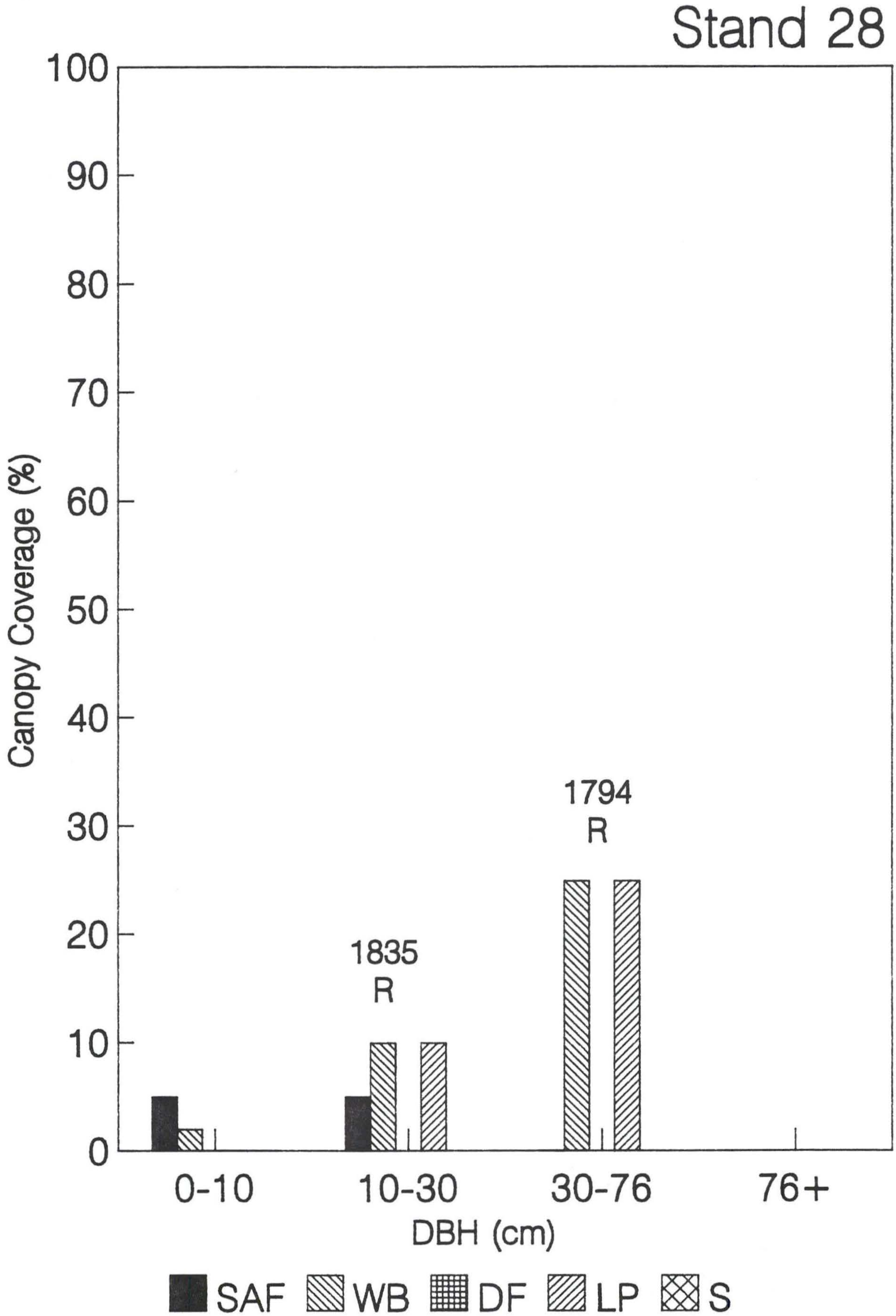

Stand 2
To 80%
1794
R
30
20
10
0
Canopy Coverage (%)
0-10
10-30
30-76
76+
DBH (cm)
SAF
WB
DF
LP
S

Fig 6



Stand 28
100
90
80
70
60
50
40
30
20
10
0
Canopy Coverage (%)
1835
R
1794
R
0-10
10-30
30-76
76+
DBH (cm)
SAF
WB
DF
LP
S

Fig 7

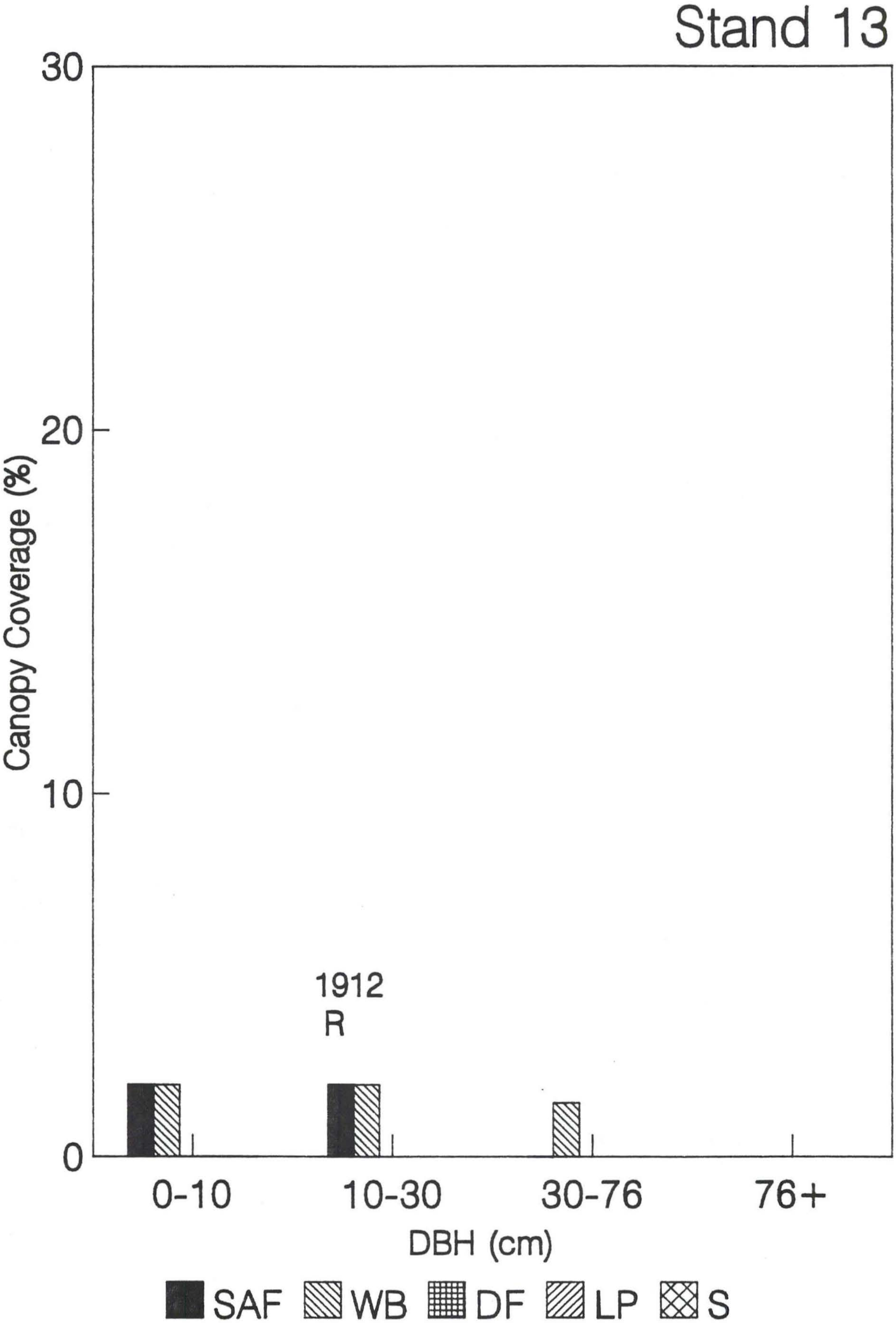

Stand 13
30
20
10
0
Canopy Coverage (%)
1912
R
0-10
10-30
30-76
76+
DBH (cm)
SAF
WB
DF
LP
S

Fig 8

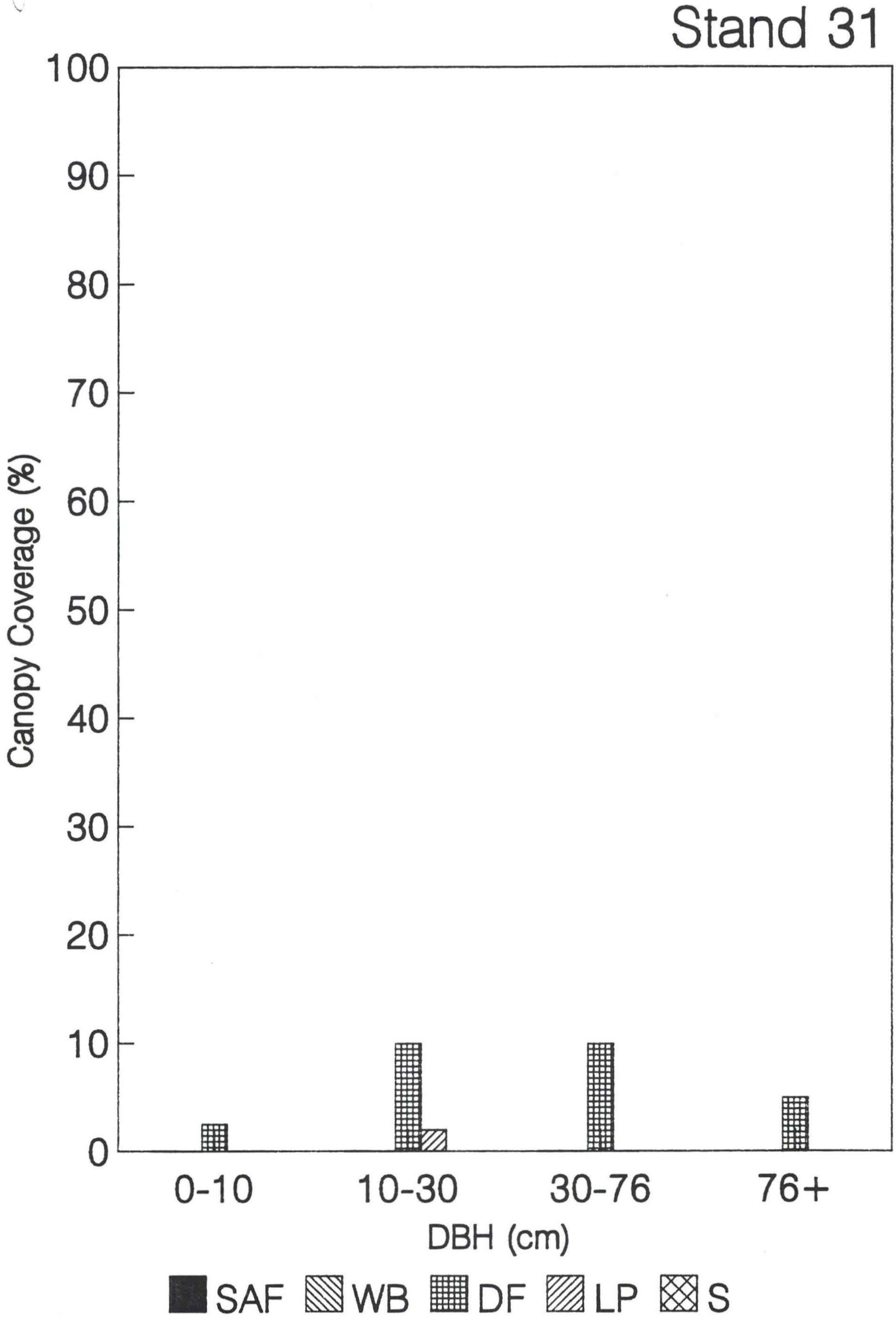

Stand 31
Canopy Coverage (%)
100
90
80
70
60
50
40
30
20
10
0
0-10
10-30
30-76
76+
DBH (cm)
SAF
WB
DF
LP
S

Table 1. Stand replacing fires between 1647 and 1991 in the 36,210 ha lodgepole pine dominated forest (* = major fires). Master fire chronology extends from ~1737-1991; portions of all classes except 1794 replaced during 1988 fire.

Est. Fire Year[1]	Estimated Hectares	% of Area	1988 Interval (yrs)
1647*	905	3	341
1737	225	1	251
1740*	2400	7	248
1750*	1469	4	238
1756*	4080	11	232
1773*	7141	20	215
1780	415	1	208
1784	776	2	204
1793	571	2	195
1794	471	1	N.A.
1805	644	2	183
1810	243	1	178
1820*	3099	9	168
1825	32	<1	163
1827	400	1	161
1835*	3967	11	153
1855*	2255	6	133
1870	773	2	118
1875	777	2	113
1898	441	1	90
1912	17	<1	76
1923	19	<1	65
1926	69	<1	62
1941	71	<1	47
1988*	27,000+	75	-

Fire frequencies:
Based on all age classes: Interval Range: 47-341 yr, MAFI: 168 yr
Based on 17 classes comprising most of 1988 burned area:
Interval Range: 113-341 yr, MAFI: 210 yr

[1] Unlisted polygons:
1750/1820 (40 ha, <1%)
1756/1835 (74 ha, <1%)
1784/1805 (219 ha, 1%)
1784/1835 (149 ha, <1%)
1835/1898 (106 ha, <1%)
Unidentified 1900s regeneration (580 ha, 2%)
Unidentified 1800s regeneration (1252 ha, 3%)
Unidentified 1700s regeneration (2527 ha, 7%)

Table 2. Fire occurrence data for 11 high elevation whitebark pine stands (Abla/Vasc/Pial h.t.)(t = timberline stands).

Stand No.	Elev. (m)	Max. Age[2] (yr)	Master Fire Chronology (yr)	No. Fires[5]	Interval Range[3] (yr)	Current Interval[4] (yr)	MFI (yr)
13t	2987	458	1724-1988	5*	26-99	3	66
14	2774	227	1756-1988	3*	76-153	3	116
49t	2835	408	1580-1988	3*	160-248	3	204
50	2780	410	1580-1988	2	(408)	3	N.A.
101	2682	455	1533-1988	2	(455)	3	N.A.
102t	2880	317	1674-1991	0	(317+)	317	N.A.
103t	2950	220	1771-1988	1	(220)	3	N.A.
104	2835	251	1740-1988	2	(248)	3	N.A.
106	2755	215	1776-1991	0	(215+)	215	N.A.
107t	2926	189	1802-1991	0	(189+)	189	N.A.
109t	2853	272	1716-1988	3	89-183	3	136

MAFI for stand replacing fires in 8 stands: 338 yr

[2] As of 1991 or 1988.

[3] + = interval length in 1991; parentheses list single intervals.

[4] As of 1991.

[5] * = category includes both lethal and non-lethal surface fires.

Table 3. Fire occurrence data for 3 Douglas-fir stands (Psme/Syal or Psme/Caru h.t.) at the grassland/forest ecotone near lower Soda Butte Creek.

Stand No.	Elev. (m)	Max. Age[6] (yr)	Master Fire Chronology (yr)	No. Fires[9]	Interval Range[7] (yr)	Current Interval[8] (yr)	MFI (yr)
10	2066	259	1766-1870	4	17-44	121	35
31	2096	506	1534-1988	11	14-110	3	45
33	2243	367	1756-1940	3	70-114	51	92
Fires, 3-stand cluster:			1534-1988	15	4-114	3	32

[6] As of 1991 or 1988.

[7] + = interval length in 1991; parentheses list single intervals.

[8] As of 1991.

[9] * = category indicates primarily non-lethal surface fires.